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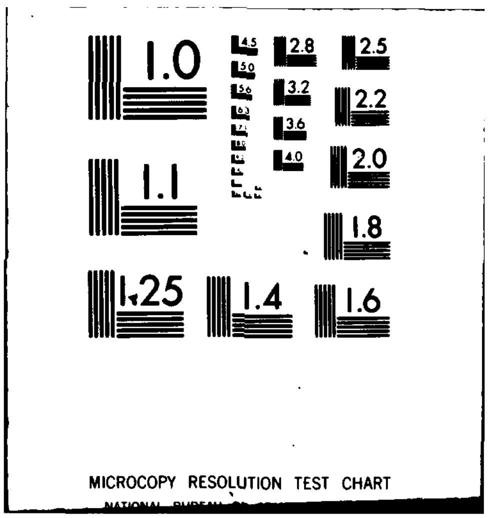
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MODELING THE ENERGY AND FUEL SECTORS IN SOVMOD

Final

February 1979

Technical Note
SSC-TN-5943-5

By: Daniel L. Bond

Prepared for:

Office of Economic Research
Central Intelligence Agency
Washington, D.C.

Contract 77N004691-000

SRI Project 5943

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Approved for Review Distribution:

Richard B. Foster, Director
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ABSTRACT

This report describes the data base, modeling concepts, and equations of the new energy and fuel component being introducted into the SRI-WEFA Soviet Econometric Model (Version III).

FOREWORD

This technical note represents research undertaken for the SSC's Soviet and Comparative Economics Program in the further development of the SRI-WEFA Econometric Model of the Soviet Union. The original Soviet Model Project was a three-year effort sponsored by the Defense Advanced Research Projects Agency, and was a cooperative research undertaking with the Wharton Econometric Forecasting Associates, Inc..

This report, authored by Daniel L. Bond, describes work on model development aimed at introducing a more detailed energy and fuel componenet into the macroeconometric model. The author wishes to gratefully acknowledge the advise and assistance of Leslie Dienes and Albina Tretyakova.

Richard B. Foster

Senior Director

Strategic Studies Center

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I. INTRODUCTION

The role that the Soviet Union may play in shaping the future world energy situation has recently attracted the attention of U.S. policy makers. In a series of reports issued by the Central Intelligence Agency during 1977, the possibiltiy was raised that Soviet oil production would significantly slowdown during the 1980's, with a possible result being that the CMEA (USSR and Eastern Europe) might shift from its current position as a modest net exporter to a substantial net importer of oil by 1985.[1] Much of the pessimism expressed by the CIA on the world energy situation in the 1980's is tied to this particular forecast.[2]

The CIA studies have recieved considerable comment, and other analyses have appeared.[3] Although there remains much conflicting opinion as to possible Soviet responses, there does exist general agreement among Western analysts that Soviet oil production will not be capable of keeping up with growing demands of domestic users while at the same time supplying most of East European needs and expanding hard currency exports as planned. In fact, the majority of analysts agree that the Soviet oil industry is in trouble. Insufficient past exploratory drilling and the adverse geological conditions of most future fields are alone major obstacles. These are further compounded by the unusually rapid depletion of existing fields. And the difficulties

of acquiring adequate hard currency for the purchase of advanced Western technology and equipment presents yet another growing problem.

In attempting to provide a comprehensive assesment of future energy situations it is necessary to couple supply forecasts with demand forecasts. It is the concept of a "gap" between these that is at the heart of any analysis of possible policy responses. In the Soviet case there are well researched and documented projections of domestic production of oil (and the other major fuels). But the future of domestic demand has yet to be as carefully studied. Most current Western demand projections are based on aggregate fuel use to GNP ratios. Considering the possibilities of energy conservation measures, interfuel substitution and changes in the pattern of economic growth for affecting this ratio, this approach leaves much to be desired.

An important component of any analysis of domestic demand for energy and fuels is an ability to develop detailed forecasts of the level and nature of future economic activity. The SRI-WEFA Soviet Econometric Model (SOVMOD) was developed, and has been used now for several years, as a tool for making such forecasts.[4] Although the major energy and fuel sectors were separately identified in SOVMOD, the linkages between production of coal, petroleum products and electric power and demand for these energy sources by other branches of the economy were not defined in such a way as to provide for endogenous generation of fuel demand forecasts. Thus, in order to enhance the usefulness of SOVMOD for energy studies, an effort has been made to introduce a more detailed protrayal of the energy and fuel components

within the model. The purpose of this paper is to describe these new features of the model, including the conceptual framework, database, and estimation results behind their development. (The version of SOVMOD which was used as a starting point for this effort SOVMOD III-C. With the introduction of the new energy and fuel components the model has been redesignated SOVMOD III-D.)

A note of caution should be added at the very beginning of this presentation. In terms of our understanding of the role of energy in Soviet economic growth, or even basic descriptive knowledge of the various energy and fuel flows within the economy, we are still at a very primitive level. Most specifications of the relationship between fuel needs and economic activity used in the model are very simple --sometimes they are no more than time trends when we have no basis for the specification other than a belief that changes (in fuel substitution or efficiency) occur rather smoothly and gradually over time. In numerous cases we have obtained "econometric results" using as few as three or four observations (separated by five year periods). Thus the reader should be aware (and users of the model beware) that any sophistication that may seem to be present in the results is quite superficial. It is hoped, however, that what is presented here can be used as a basis for building a firmer foundation for understanding this important aspect of the Soviet economy.

II. OVERVIEW OF THE MODEL STRUCTURE

The new energy and fuel component of SOVMOD can be broken down into three components. First, and most important in terms of our ability to make forecasts in this area, are the demand equations. These use the values of various demographic and activity variables generated in SOVMOD to determine energy requirements by major type (electrical, thermal, and direct motor), which are then translated in fuel requirements for coal, oil and gas. A second group of equations gives levels of labor and capital inputs going into the fuel sectors, and provide output levels. Since it is expected that in many instances the model will be used to test out the impact of exogenously set levels of production in the fuel sectors, these equations have been designed to facilitate this process, while at the same time maintaining the integrity of the overall system of factor allocation equations. A third group of equations are provided in the foreign trade block which serve to disaggregate fuel trade by fuel type and region (East Europe and rest of the world). Links are provided between these equations and the existing foreign trade system--a process entailing the introduction of price variables and equations--so that balance of payments impacts of Soviet fuel trade policy can be analyzed.

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In this overview section only the first of these components will be examined. The other two are discussed in later sections when the specific equations are presented. These latter components are designed primarily to provide the detail and structure that is necessary in order to allow the analyst to manipulate the model in ways representative of alternative Soviet fuel production and trade strategies. In many cases, a substantial number of variables may even be exogenized and their values set by assumption.

The heart of the system that we have introduced is the energy and fuel demand component. As far as we know, this represents the first Western attempt to model Soviet fuel demand in any detail. Earlier efforts to project Soviet fuel use have relied upon aggregate fuel to GNP time trends, or have been based on a fixed input coefficient basis.[5] In the approach taken here the emphasis is on forecasting energy requirement trends in such a way that these can be used to generate estimates of demand for specific fuels, where explicit consideration is given to the possibilities for interfuel substitution.

A diagram of the major variables, and their interrelations, found in this component of the model is provided in Figure 1.

The determination of fuel demands is made in two steps. First, energy demands are forecast on the basis of production and population levels generated in the macromodel. Three major classes of energy demand are identified: (1) electrical power, (2) thermal energy, and

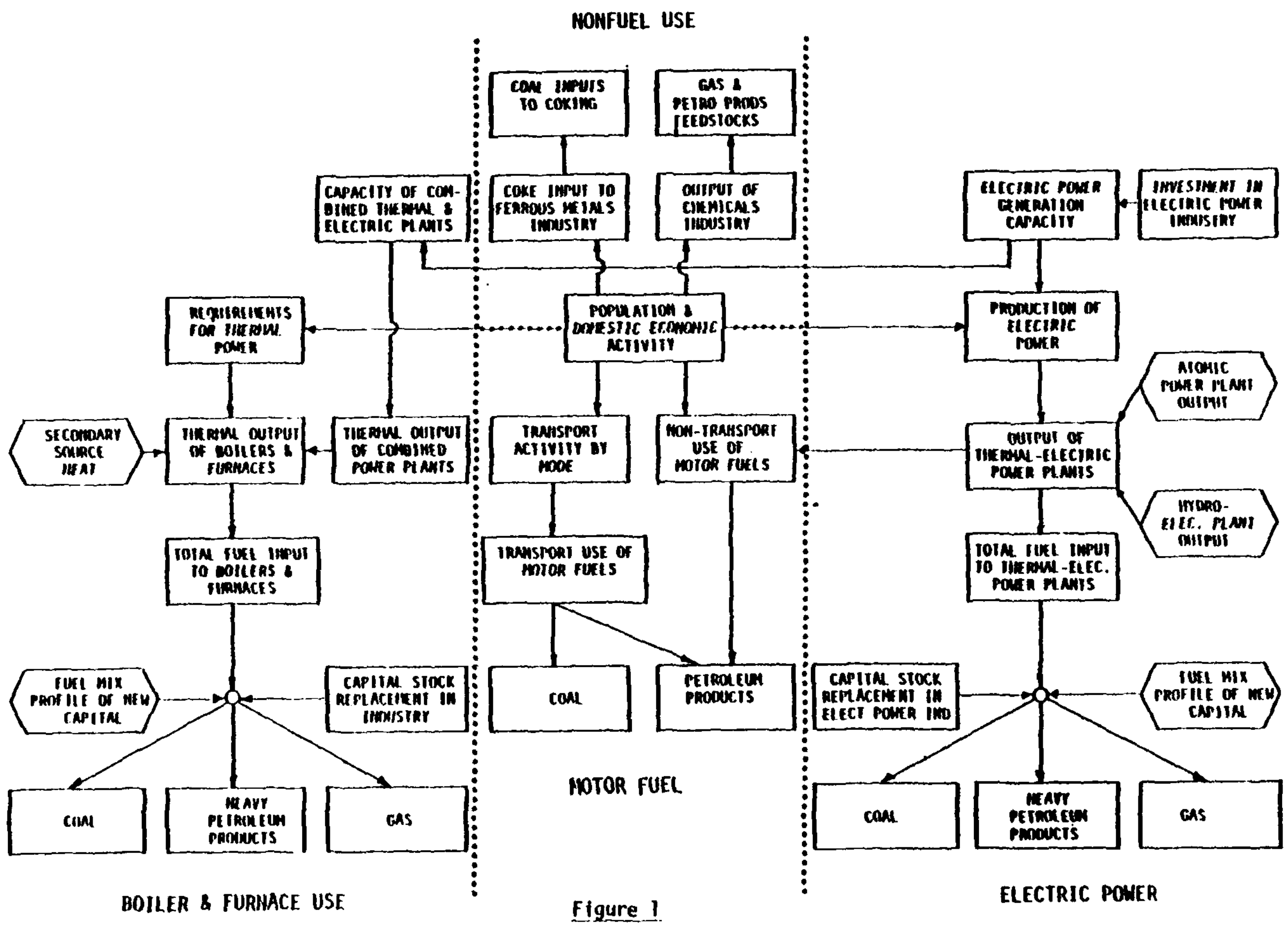


Figure 1

A SIMPLIFIED DIAGRAM OF
THE ENERGY & FUEL CONSUMPTION SECTOR IN SOVMOD III

(3) direct motor power. Not only are these energy forms distinguishable by the nature of their use, but each can be associated with particular types of equipment needed for their generation. The technical characterists of this equipment determine both the type of fuels required to generate this energy, and the degree of fuel substitutability that is possible.

There are possibilities for substitution to occur among the various energy types. Electric motors can replace gasoline driven motors, and electric heat can replace boiler and furnace heat in industrial processes and home heating. We do not, however, attempt to explicitly model such substitutions. These changes normally occur very gradually, and any major shifts that are already underway are probably captured in our equations since most have included in them either a time trend variable or some other variable which changes monotonically with time. We also feel that most Soviet efforts aimed at changing fuel use patterns will be focused on inter-fuel substitution within each form of energy production, and not at major changes in the forms of energy use themselves.

In the second step referred to above, we address specifically this issue of fuel substitution.[6] The major places where substitution among fuels of any significant degree can occurs are in the electric power plants and in boiler and furnace use. Over the past 15-20 years, there have been significant shifts in the fuel mix at these points, and together these uses make up over 70% of domestic fuel consumption.

(See Table 1 and Figures 2 and 3.) It is assumed that direct motor power will continue to be based on the use of light petroleum products.

In modeling inter-fuel substitution we have embraced the so-called "putty-clay" model of input requirements.[7] That is, we assume that fuel input requirements of capital stock already in use will not change significantly, and that the fuel mix observed in any given year (which when expressed in terms of shares of total fuel use we will call the "average" fuel mix coefficients) is a weighted average of the fuel input requirements of the various vintages of capital stock still in use (where the weights are the shares of each vintage in total capital stock). Faced with changing relative prices or scarcities of fuels it is expected that there will be an attempt to replace the dearer fuels with the less dear. But this can be accomplished only by the introduction of new equipment designed for this purpose, the "vintage" coefficients of which reflect a mix of fuels more economical in terms of the changing conditions of fuel supply.[8]

We have not attempted to endogenously determine fuel mix changes in new investment. It was felt that this could be better carried out for purposes of forecasting by detailed and expert analysis carried on outside the bounds of SOVMOD.[9]

In addition to the variables for which values are determined within the model, there are a number of variables needed to complete the system for which values must be set by assumption. These are indicated in Figure 1 by the hexagonal boxes, and include output

of atomic and hydro-electric power plants, and secondary recovery of heat in industrial processes. We also have accounted for uses of fuels as material inputs in the ferrous metal and chemical industries by means of input functions linked to production levels in these industries (and by exogenous assumptions for the mix of fuels used for petrochemical feedstocks).

III. DATA SOURCES

In approaching the task of modeling the energy and fuel sectors of the Soviet economy, we were fortunate in having access to a newly compiled set of energy balance matrices prepared by Professor Robert Campbell.[10] The Soviets have been preparing comprehensive fuel and energy balances on a periodic basis since 1960. Although there are many deficiencies in the published statistics in this area, this is an important source of information. Professor Campbell has used data from published portions or descriptions of these balances, together with various supplementary source statistics, to construct a set of balances for the years 1950, 1960, 1965, 1970 and 1975.

These matrices are structured primarily on a fuel type/sector of use basis. That is, for each fuel and energy source there is shown the amounts used in the various sectors of the economy--industry, agriculture, transport, construction, household and municipal. Also intra-sector transfers (coal to coke, crude oil to refined petroleum products, etc.), losses and consumption within the producing sectors, and net trade flows are also depicted. However, the model as we have structured it requires that energy and fuel use be identified by type (for generating electric power, thermal energy, or direct motor drive, and for use as a material input), as well as by sector of use. While Campbell identifies two of these use--use of fuel in electric power

plants and direct use--the others are not identified. Thus, it was necessary to regroup the data in Campbell's matricies to conform to this requirement.

In this regrouping it has been necessary to make a number of assumptions as to the nature of fuel uses and types. In some cases these assumptions are such that the resulting balances can only be considered as rough approximations to the actual flows. We feel that the advantage for modeling of grouping uses in terms of processes with similar fuel substitution possibilities is sufficient to warrant the inaccuracies that doubtlessly arise in this process. We wish to stress that the deficiencies in the resulting energy and fuel matricies, which we use in this paper, should not reflect upon Professor Campbell's work. The quality underlying this data base should be attributed to his efforts, the distortions produced in the data by our use of it should be attributed to us.

On the basis of the Campbell data, the matrix of fuel uses presented in Table 1 was constructed and serves as a primary source of data for the model. In comparison with Campbell's matrices a number of differences, besides the column classification system we use, should be noted. First, the distribution of electric and thermal power is not included here. We used other data sources for these secondary energy allocations. These data are presented in later sections of this paper as we discuss the equations used to depict these flows.

Second, petroleum products have been disaggregated into light and

Table 1

BASIC DATA ON SOVIET DOMESTIC FUEL USES

1960 1965 1970 1975	ELECTRIC POWER PLANTS	MATERIAL INPUT	BOILERS & FURNACES	MOTOR FUEL	TOTAL
COAL	113.8 131.5 151.8 195.4 UCOXELTP	50.4 59.6 66.6 74.4 UCOKE	99.3 106.9 146.8 119.3 UCOBF	40.3 39.3 20.0 16.3 UCOMF	303.8 337.3 385.2 405.4 UCO
HEAVY PETROLEUM PRODUCTS	12.2 30.6 73.5 136.0 UPPXELTP	6.9 4.7 16.2 15.9 UHPPFSK9	31.3 40.8 41.0 94.1 UPPBF	14.5 14.0 13.4 12.9 UHPPMF9	64.9 90.1 144.1 258.9 UHPP
LIGHT PETROLEUM PRODUCTS		3.4 2.4 8.1 8.0 ULPPFSK9		75.9 123.4 165.8 176.9 ULPPMF	79.3 125.8 173.9 184.9 ULPP
GAS	15.7 50.9 71.2 87.7 UGAXELTP	4.7 14.9 16.5 33.9 UGAFSK9	28.8 73.2 130.2 186.8 UGABF		49.2 139.0 217.9 308.4 UGA
OTHER FUELS	14.3 16.2 18.7 17.9	4.6 6.8 5.9 7.4	75.0 72.8 64.2 63.3		93.9 95.8 88.8 88.6
TOTAL	156.0 229.2 315.2 437.0 UFXELTP	70.0 88.4 113.3 139.6 UFDIRECT	234.4 293.7 382.2 463.5 UFBF	130.7 176.7 199.2 206.1 UFMF	591.1 788.0 1009.9 1246.2 UF

units: million tons standard fuel equivalents

heavy products. (In light products are included diesel fuel, gasoline, and kerosene. Heavy products are residual fuel oils--*mazut*--of both furnace and naval grades.) The total amount of each was obtained from tables in the text of Campbell (1978). Their distribution by use was made on assumptions that: (1) only heavy products were used in thermal electric power plants and in boilers and furnaces; (2) motor fuel use of heavy products was limited to naval fuel; and (3) that one half of direct use (petrochemical feedstocks primarily) is of each type.

The other assumptions made are evident from the structure of Table 1. The overall aggregates of various categories correspond to those of Campbell's matrices (for a component of his domestic final use quadrant). Campbell's data on intra-sector transfers, losses and internal consumption have also been used, but with no change other than aggregation.

In the model electric and thermal power flows are measured in kilowatt hours and giga-calories. Fuel inputs in the aggregate and by type are modeled in terms of standard fuel equivalency (SFE) units, which in Soviet use has a heat content of 7,000 large calories per kilogram. They are then converted into natural units for comparison with production figures. (The approximate conversion factors by fuel type are: one ton of coal equal 0.71 ton SFE; one ton of oil equal 1.41 ton SFE; and 1,000 cubic meters of gas equal 1.22 ton SFE.) And in order to link the energy sectors to the gross national product accounts and foreign trade values, they are also converted into value terms in various instances.

IV. ENERGY AND FUEL DEMAND EQUATIONS

1. Electric Power Use

Annual data on use of electric power by major sectors of the economy -- industry, agriculture, transportation, other branches -- and transmission losses appear regularly in the Narkhoz (Narodnoe Khoziaistvo SSSR v 19--g.) It was possible to disaggregate the "other branches" into two components--construction and urban municipal and household use--using supplementary data and estimation results. (See Table 2.)

These data were used to estimate equations for use of electric power by sector. The explanatory variables chosen for the productive sectors represent measures of output, capital intensity of the sector, and an electric power supply constraint. It was expected that electric power use per unit of output (or per capita) would be directly related to the degree of mechanization of the sector, as represented by capital stock to output ratios. Although time series data on electric power use by branch of industry is not available, it was still possible to capture in the specification for total industry the impact of differing requirements across individual branches. From Nekrasov and Pervukhin (1977, pp 25-35) the following figures on electric power use by branch of industry for 1970 were obtained:

Ferrous metals	70.7 billion KWH
Non-ferrous metals	67.3 billion KWH
Chemicals	64.2 billion KWH
Petroleum products & coal	46.0 billion KWH
Machine building & working	65.6 billion KWH
Electrical power	50.5 billion KWH
Other sectors	1,24.1 billion KWH
Total Industrial	4,88.4 billion KWH

These were used, together with 1970 branch output estimates, to construct a (electrical power use) weighted measure of industrial output for use in the total industry equation.

An inverse relationship was expected between use and the ratio of total electrical power output and capacity (XELP/KELPC). This reflects a supply constraint which comes into play when generating capacity is heavily used. (It can also be seen as representing the stimulus to use that may occur as new capacity is added.)

Since agricultural output varies substantially with weather conditions, it was felt necessary to correct for the disturbance this introduces in the ratio of power use to output. An additional variable, the ratio of actual to "normal" output (based on a smoothed trend), was added to the agriculture equation. When actual output exceeds "normal" output it is to be expected that some of the change in the ratio of electric power use to output simply reflects the larger value of the numerator brought about by good weather and a bumper crop.

The major demand for electricity in transportation comes from the electrified railways. The share of such lines (in total length) has

TABLE 2

ELECTRIC POWER USE BY MAJOR SECTORS

	Industry	Agri-culture*	Transpor-tation	Urban Household & Municipal**	Con-struction**	Transmission Losses
	(UELIN)	(UELAG)	(UELTR)	(UELHHM)	(UELCN)	(UELOSS)
1960	207.5	10.0	17.7	30.4	8.9	17.8
1961	231.7	11.8	20.5	34.3	9.2	20.0
1962	260.9	14.0	23.9	37.6	9.7	23.0
1963	287.4	16.3	29.2	41.6	10.0	27.1
1964	317.8	18.6	32.9	46.5	10.6	31.2
1965	349.4	21.1	37.1	51.3	11.2	35.1
1966	372.9	23.2	40.6	55.9	11.9	38.5
1967	399.7	25.8	43.8	60.6	12.8	43.2
1968	429.9	29.2	48.7	66.6	13.5	48.3
1969	458.1	33.3	51.6	74.3	14.2	53.7
1970	488.4	38.6	54.4	81.0	15.0	58.3
1971	520.5	45.6	58.2	89.9	16.3	63.2
1972	552.9	51.6	61.5	97.9	17.1	69.3
1973	585.6	57.6	64.8	106.1	18.2	72.6
1974	620.7	65.9	68.6	113.2	19.2	77.3
1975	656.8	73.8	74.2	119.3	21.0	82.2

Units: Billion Kilowatt Hours.

* Includes rural household use.

** Estimated disaggregation of published category "other branches". (See text for estimation procedure.)

grown from slightly over ten percent in 1960 to 28% in 1975. In order to capture the impact of this and future shifts in the degree of electrification, this ratio was included in the equation for transportation. (When this was done the capital variable proved insignificant and was dropped.)

Construction sector electric power use data is available only for a few years. Using figures for 1960, 1965, 1970 and 1975 compiled by Campbell (1977), a simple relationship between the power-to-output ratio and the capital to output ratio was estimated. The estimated equation was used to generate a time series of estimates for the construction sector. The estimates for urban household and municipal use were then obtained by subtracting this series from the annual data for "other uses".

The demand equation specified for electrical power for urban household and municipal uses (specified on a urban per capita basis) was expressed as a function of a measure of accummulated consumer durables per capita and the real per capita urban wage. The electric power supply constraint is also included. (The manner in which the series was constructed probably exaggerates the impact of this constraint, since the construction use estimates are probably smoother than the actual series.)

Finally, the transmission loss equation is specified to reflect the conflicting impacts of increasing centralization in electric power production (accompanied by greater transmission distances and thus

losses) and improved transmission technology leading to loss reductions. The first is represented by change in the ratio of centralized to total electric power output, which grew from 0.88 in 1960 to 0.97 in 1975 and thus is not likely to increase much further. The second by a log time trend. The ratio of loss per unit of electrical power output grew over the period 1960-1972 and then began to decline. Given the specification used, this decline will continue in the forecast period.

(E.1) <u>EPRIND Industry Output Index Weighted by Branch Electric Power Requirements</u>

$$
\begin{aligned}
EPRIND = {} & 0.707\ XOFM + 0.673\ XONF + 0.642\ XOCH \\
& + 0.656\ XOMB + (0.654\ XOPP + 0.346\ OXCP)\ 0.46 \\
& + 0.505\ XOEP + (0.105\ XOFP + 0.170\ XOPA \\
& + 0.101\ XOCM + 0.384\ XOSG + 0.384\ XOPF)\ 1.241
\end{aligned}
$$

(E.2) <u>UELIN Industry Use of Electricity</u>

$$
\underset{(0.999)}{\frac{UELIN}{EPRIND}} = \underset{(9.25)}{1.1090} - \underset{(2.98)}{0.1086}\ \frac{XELP}{KELPC} + \underset{(6.73)}{0.16726}\ \frac{KITOT}{XOIN}
$$

$\bar{R}^2 = 0.902$ S.E.= 0.0006 D.W. = 1.81

Sample Period 1963-1975

(E.3) <u>UELAG Agriculture Use of Electricity</u>

$$
\underset{(0.496)}{\frac{UELAG}{XAGT70}} = \underset{(1.52)}{0.9389} - \underset{(1.96)}{0.299}\ \frac{XELP}{KELPC} + \underset{(11.93)}{0.9526}\ \frac{KAIR}{XAGTN} - \underset{(7.65)}{0.5328}\left(\frac{XAGT70}{XAGTN} - 1.0\right)
$$

$\bar{R}^2 = 0.995$ S.E. = 0.0139 D.W. = 1.46

Sample Period 1963-1975

(E.4) <u>UELTR Transportation Use of Electricity</u>

$$
\underset{(0.0139)}{\frac{UELTR}{HFTOT}} = \underset{(8.08)}{0.0243} - \underset{(4.33)}{0.00329}\ \frac{XELP}{KELPC} + \underset{(8.18)}{0.01956}\ RHRLE9
$$

$\bar{R}^2 = 0.874$ S.E. = 0.00019 D.W. = 2.27

Sample Period 1963-1975

(HFTOT is defined in equation E.18.)

(E.5) UELHHM Urban Household and Municipal Use of Electricity.

$$\frac{UELHHM}{NPOPU} = \underset{(1.23)}{0.668} - \underset{(1.70)}{0.2065}\frac{XELP}{KELPC} + \underset{(4.01)}{0.5045}\frac{ZWUM}{NPOPU}$$
(0.508)

$$+ \underset{(4.33)}{0.7546} \frac{\sum_{t=0}^{6} CRD70_{-t}}{NPOPU}$$

$\bar{R}^2 = 0.995$ S.E. = 0.0126 D.W. = 1.16

Sample Period 1960-75

(E.6) UELCN Construction Use of Electricity

$$\frac{UELCN}{XOCN} = 0.1394 + 0.0823 \frac{KCR}{XOCN}$$

(Fitted to Data for 1960, 1965, 1970, 1975.)

(E.7) UELOSS Transmission Losses of Electricity

$$\left(\frac{UELOSS}{XELP} / \frac{UELOSS_{-1}}{XELP_{-1}}\right) - 1.0 = \underset{(1.07)}{0.0468} - \underset{(1.00)}{0.01393}\, QLT50$$
(0.0178)

$$+ \underset{(3.85)}{1.79952} \left(\frac{XELPCTL9}{XELPCTL9_{-1}} - 1.0\right)$$

$\bar{R}^2 = 0.603$ S.E. = 0.012 D.W. = 1.88

Sample Period 1961 - 1975

2. Electric Power Production

Output of electrical power is demand determined in the model. That is, total output is calculated as the sum of uses as determined by the above six demand equations, plus exports of electricity. Since four of these equations contain a supply constraint (in the form of the ratio of electric power output to production capacity--with a negative coefficient for this variable), generation capacity of power stations is a determinant of both supply and demand. For the model this information is given in the form of separate variables for electric power generating capacity of thermal-, hydro-, and atomic-powered stations. (See Table 3.) Since only output of thermal-powered stations is used in determining hydro-carbon fuel requirements for producing electricity, equations are provided for linking the output of the other two types of stations to their exogenously given capacities. Total capacity being a function of capital stock, the capacity of thermal-power stations is given as a residual value. Likewise, output of thermal stations is found as a residual after hydro- and atomic-power station output is subtracted from total electric power demand.

In the determination of thermal power fuel requirements (see below), there is a need for estimates of thermal power produced in conjunction with electric power generation. This process is carried out in the so-called TETS (teploelektrotsentral) plants. For this purpose a time-trend equation linking capacity of TETS stations to total capacity is provided.

TABLE 3

ELECTRIC POWER PRODUCTION

	Total	Thermal	Hydro	Atomic*
	XELP	XELTP	XELHP	XELAP
1960	292.27	241.36	50.91	0.00
1961	327.61	NA	59.12	NA
1962	369.27	NA	71.94	NA
1963	412.42	NA	75.86	NA
1964	458.90	NA	77.36	NA
1965	506.67	423.84	81.43	1.40
1966	544.57	NA	91.82	NA
1967	587.70	NA	88.57	NA
1968	638.66	NA	104.04	NA
1969	689.05	NA	115.18	NA
1970	740.93	613.05	124.38	3.50
1971	800.36	670.26	126.10	4.00
1972	857.43	727.24	122.90	7.30
1973	914.61	780.56	122.34	11.70
1974	975.75	825.72	132.03	18.00
1975	1038.60	892.62	125.99	20.00

Units: billion kilo-watt hours

ELECTRIC POWER GENERATING CAPACITY

	Total	Thermal	Hydro	Atomic**
	KELPC	KELTPC9	KELHPC9	KELAPC9
1960	66.72	51.94	14.78	0.0
1961	74.10	NA	16.36	NA
1962	82.46	NA	18.62	NA
1963	93.05	NA	20.83	NA
1964	103.58	NA	21.25	NA
1965	115.03	92.59	22.24	0.2
1966	123.01	NA	23.08	NA
1967	131.73	NA	24.81	NA
1968	142.50	NA	27.04	NA
1969	153.79	NA	29.65	NA
1970	166.15	133.88	31.37	0.9
1971	175.36	NA	33.45	NA
1972	186.24	NA	34.85	NA
1973	195.56	NA	35.32	NA
1974	205.44	NA	36.98	NA
1975	217.48	172.27	40.52	4.7

Units: million kilo-watts

* Source: Jack, et al. (1976), p. 462, Table 1.
** Source: Nekrasov & Pervukhin (1977), p. 11, Table 1-1.
Other data from *Narkhoz* or estimated as a residual.

(E.8) XELP Total Electric Power Production

$$XELP = UELIN + UELAG + UELTR + UELHHM + UELCN + UELOSS + EFTEP$$

(E.9) XELAP Electric Power Production of Atomic Stations

$$XELAP = (3.77 + 0.0164\ QT50)\ KELAPC9$$

(Fitted to time series for XELAP interpolated from data for 1965, 1970 & 1975).

(E.10) XELHP Hydro-Electric Power Production

$$\underset{(112.3)}{XELHP} = \underset{(2.36)}{28.605} + \underset{(7.03)}{2.712}\ KELHPC9$$

$\bar{R}^2 = 0.829$ S.E. = 7.33 D.W. = 1.23

Sample period 1965 - 1975

(E.11) *XELTP Electric Power Production of Thermal Power Stations*

$$XELTP = XELP - XELAP - XELHP$$

(E.12) KELPC Total Electric Power Generating Capacity

$$\underset{(5.45)}{\frac{KELPC}{KIEP}} = \underset{(45.32)}{14.166} - \underset{(28.01)}{3.022}\ QLT50$$

$\bar{R}^2 = 0.982$ S.E. = 0.11 D.W. 2.07

Sample Period 1960 - 1975

(E.13) KELTPC Thermal-Electric Power Station Capacity

$$KELTPC = KELPC - KELAPC9 - KELHPC9$$

(E.14) KELTETS Capacity of TETs Stations

$$\frac{KELTETS}{KELPC} = 0.1518 + 0.039\ QLT50$$

(Fitted to time series for KELTETS interpolated from data for 1965, 1970, & 1975.)

3. Fuel Requirements For Electric Power Production

Total hydro-carbon fuel requirements (in million tons of standard fuel equivalency--SFE--units) for electric power production in thermal-electric plants is determined on a per unit output basis. Because efficiency in generation has changed over time, a log time trend is used to estimate the rate of technological improvement. Another factor which has probably contributed to increasing fuel efficiency has been the shift from coal to oil and gas. The use of standard fuel equivalency units, as defined in Soviet sources, almost certainly leads to overstaing efficiency improvements since the conversion rate used for coal is too high. In order to correct for both real efficiency differences between coal and other fuels and the statistical bias of Soviet figures, a correction term was added to the fuel requirement equation.

The Soviet conversion coefficient has been approximately 0.7 tons SFE per ton of coal for the sample period. To estimate the correction factor we have used the following conversion rates: 0.3 tons SFE per ton of brown coal and 0.7 tons SFE per ton of hard coal. Since approximately 75% of Soviet coal output is hard coal, this means that the official conversion ratio for coal is approximately 15% too high. Thus the total fuel use value was corrected by subtracting from it 0.15 SFE units per SFE unit of coal used.

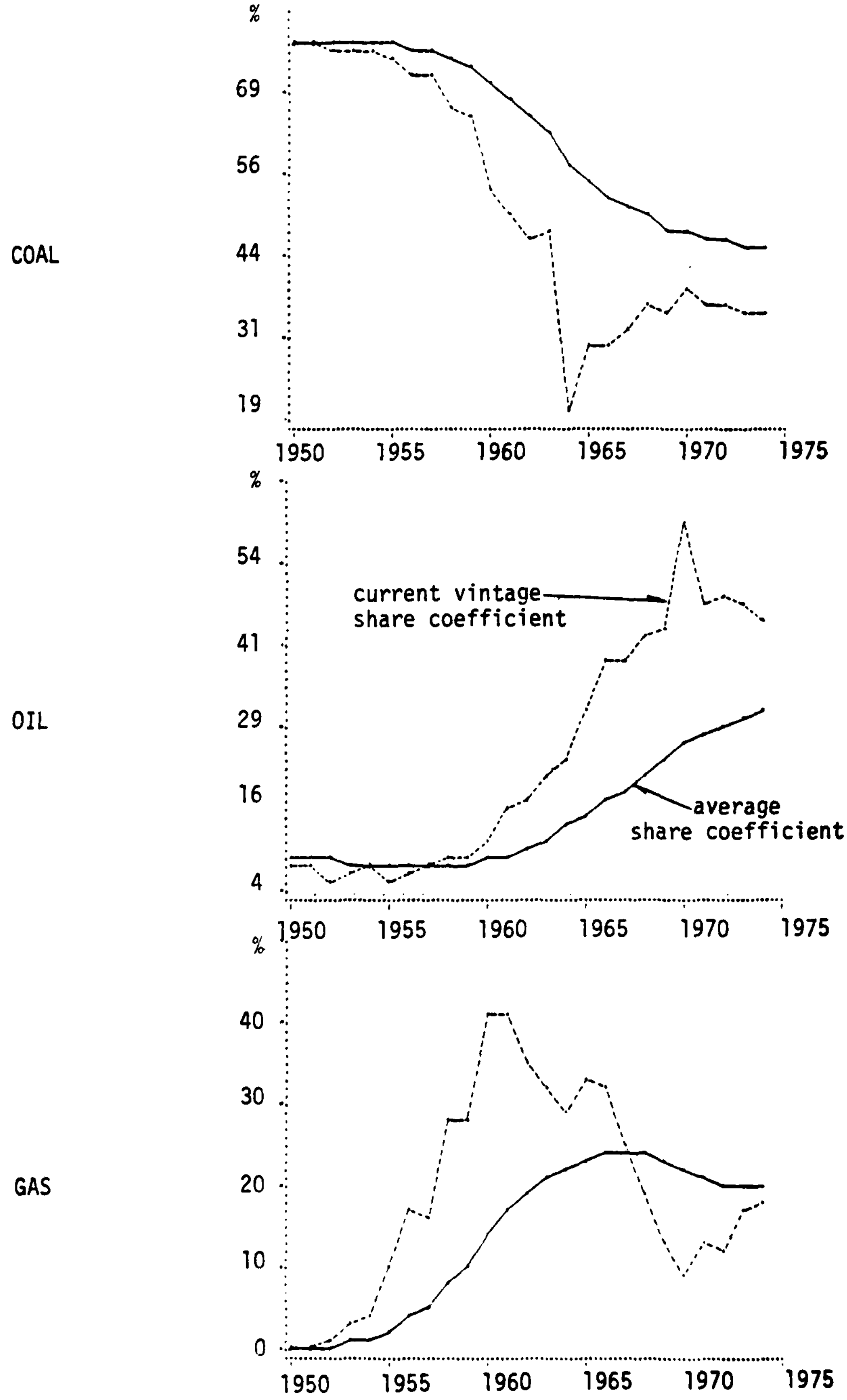
In determining the fuel mix used in electric power plants we have followed the procedure outlined in the overview section. This means that the fuel mix is determined by the requirements of the various

vintages of capital stock in use at a given time. (In the following equations generating capacity is used in place of capital stock). Since we do not attempt to endogenously determine change in fuel mix requirements of new capital, these equations are simply identities in the model. (The assignment of values to these requirements for future time periods is one of the most important aspects in forecasting for the energy sector).

The relationship between average and vintage coefficients is well illustrated using the available data on use of coal, oil, and gas for electric power generation. We are limited in data on these inputs to only five observations--for 1950, 1960, 1965, 1970, and 1975. However, if we interpolate for the intervening years (graphically using a spline), we obtain time series which can be used in calculating average fuel shares such as those presented in Figure 2. Using historic data on generation capacity in thermal-electric power plants, and assuming that real depreciation is two percent of capacity per year, we can calculate the corresponding vintage coefficients. These are also shown in Figure 2. From these figures it appears that the shift in fuel mix for new capacity away from oil and toward coal and gas was already underway by 1975.

Figure 2

FUEL MIX IN ELECTRIC POWER PLANTS



(E.15) UFXELTP Fuel Use in Thermo-Electric Power Plants

$$\frac{UFXELTP - 0.15\ UCOXELTP}{XELTP} = 0.4568 - 0.12208\ (QLT50 - 3.2581)$$

(Fitted to data for 1960, 1965, 1970, 1975.)

(E.16) UCOXELTP, UPPXELTP, UGAXELTP
Coal, Oil & Gas Use in Thermo-Electric Power Plants

$$\frac{U\&XELTP}{UFXELTP} = CM\&E9\ \left(\frac{KELTPC9-0.98\ KELTPC9_{-1}}{KELTPC9}\right)$$

$$+ \left(\frac{U\&XELTP_{-1}}{UFXELTP_{-1}}\right)\ 0.98\ \left(\frac{KELTPC9_{-1}}{KELTPC9}\right)$$

for & = CO, PP, GA

4. Motor Fuel Use

Four categories of motor fuel use are identified in the model: (1) automobile use, (2) other transporation sector use of light petroleum products, (3) transportation sector use of coal, and (4) non-transportation sector use of light petroleum products. The specifications used are very simple since the data available is both limited and based on a number of rather shaky assumptions, as was discussed above.

For the automobile use calculations the following estimates were made. First the stock of autos in use over the sample period was obtained using data on auto production and trade for 1950-1975. (See Table 4). It was assumed that autos were used for ten years and then scrapped, and that the stock was negligible in 1950. Thus the stock of autos in use (KAUTO) was calculated as:

$$KAUTO = \sum_{i=0}^{10} (XAUTO_{-i} - EAUTO_{-i} - EAUTOD_{i})$$

Then a crude guess at fuel use per auto was made. Using figures of 5000 miles per year of use, and 20 miles per gallon for fuel efficiency, a figure for light petroleum product requirements per auto per year of one ton SFE was obtained.[11]

An endogenous determination of the auto stock is included in the model. In 1975, the ratio of autos to population was 0.017. Using a logistic curve formulation, where the asymptote is set at 0.25 autos

TABLE 4

DATA USED IN ESTIMATING STOCK OF AUTOMOBILES

	Production of Automobiles (XAUTO)	Export of Automobiles (EAUTO)	Export of Autos in Disassembled Form (EAUTOD)	Estimated Stock of Automobiles (KAUTO)
1950	64.55	5.20	.00	NA
1951	53.65	4.80	.00	NA
1952	59.66	5.30	.00	NA
1953	77.38	8.80	.00	NA
1954	94.73	11.40	.00	NA
1955	107.81	12.90	.00	NA
1956	97.79	17.50	.00	NA
1957	113.59	23.00	.00	NA
1958	122.19	21.70	.00	NA
1959	124.52	36.00	.00	NA
1960	138.82	30.20	.00	877.89
1961	148.91	32.80	.00	934.65
1962	165.95	39.70	.00	1012.00
1963	173.12	35.70	.00	1095.10
1964	185.16	44.50	.00	1167.20
1965	201.18	48.60	.00	1236.40
1966	230.25	66.50	.00	1305.30
1967	251.44	68.90	1.50	1406.00
1968	280.33	82.30	2.90	1510.60
1969	293.56	73.80	5.70	1624.10
1970	344.20	83.60	7.00	1789.00
1971	529.00	149.70	7.10	2052.60
1972	730.10	194.90	8.80	2462.90
1973	916.70	237.50	9.90	3005.90
1974	1119.00	287.30	15.10	3685.10
1975	1201.00	295.60	14.60	4435.20

Units: Thousands

Source: Production figures from Narkhoz and trade data from Vneshniaia Torgovlia (various years). Stocks estimated as described in text.

per capita, and fitting this curve to 1971-75 data, gives a growth curve for this variable.[12] However, it is desirable that alternative estimates be made and introduced by assumption.

Other transportation use of light petroleum products are linked to changes in total freight turnover, which, in turn, is related to growth in agricultural, industrial, construction, and military output measures.

Also, since coal and oil shipments are a substantial share of this turnover, a variable representing the eastward shift in the extraction location of these minerals is included. The ratio of fuel use to frieght turnover was thus specified simply with a log time trend.

The primary use of coal in transportation is for the railroads, and gradually diesel and electric driven locomotives are replacing the coal driven ones. A logistic function with an asymptotic value of 0.1, was used to represent this declining use of coal.

A small amount of residual fuel oil (naval grade) is used in ship's boilers. This demand is included in the model with an exogenous variable.

Use of motor fuels outside the transport sector per unit value of non-transport production was fitted to a log time trend.[13]

(E.17) KAUTO Stock of Autos

$$\ln \left(\frac{0.25}{\underset{(3.07)}{KAUTO/NPOP9/1000}} - 1\right) = \underset{(52.6)}{7.412} - \underset{(30.9)}{0.185}\ QT50$$

$\bar{R}^2 = 0.995$ S.E. = 0.025 D.W. = 1.38

Sample Period 1970-75

(E.18) HFTOT Total Freight Turnover

$$\frac{HFTOT}{\underset{(15.16)}{D.GNP}} = \underset{(2.19)}{6.164} + \underset{(2.15)}{9.395} \left(\frac{XOIPEU + XCOPEU}{XTOIP + XTCOP}\right) + \underset{(1.33)}{1.866}\ QLT50$$

where $D.GNP = 1.57\ XOIN + 0.254\ XOCN + \frac{5.32}{3.535}\ NMD9 + \frac{0.705}{0.741}\ (XAGT70 - AVCP70)$

$\bar{R}^2$ = 0.932 S.E. = 0.208 D.W. = 2.02

Sample Period 1965-75

(E.19) UFLPPT Transport Sector Use of Light Petroleum Products

$$\frac{UFLPPT}{HFTOT} = 0.04644 - 0.01006\ QLT50$$

(Fitted to data for 1960, 1965, 1970, 1975.)

(E.20) UCOMF Use of Coal in Transport

$$\ln \left(1. - \frac{0.1}{UCOMF}\right) = 0.000935 - 0.000269\ QT50$$

(Fitted to data for 1960, 1965, 1970, 1975.)

(E.21) UFLPPNT Use of Motor Fuels Outside the Transport Sector

$$\frac{UFLPPNT}{D.OUTPUTNT} = -0.128 + 0.1577\ QLT50$$

where $D.OUTPUTNT = 1.57\ XOIN + 0.254\ XOCN$

$$+ \frac{5.32}{3.535}\ NMD9 + \frac{0.705}{0.741}\ (XAGTN - AVCP70)$$

(Fitted to data for 1960, 1965, 1970, 1975.)

(E.22) ULPPMF Total Motor Fuel Use of Light Petroleum Products

$$ULPPMF = UFLPPT + UFLPPNT + KAUTO/1000.$$

5. Thermal Energy Use

For estimates of thermal energy use by sector, we are again faced with very limited data. Two classes of thermal energy are often distinguished in Soviet statistics. The first is medium- and low-temperature heat for industrial processing or home and communal needs, which is generated in boilers and transmitted in the form of steam and hot water. The second is high-temperature (greater than 400°-600° C.) heat produced in industrial furnaces primarily for processing of ferrous metals and construction materials. We will refer to the two classes of thermal energy simply as boiler heat and furnace heat.

Use of boiler heat is described in Nekrasov & Pervukhin (1977, Chapter 4) and Pavlenko & Nekrasov (1972, Chapter 4). These sources provide data which made it possible to calculate for various years ratios of thermal energy use to industrial output and urban population, and transmission loss to total output, which were then fitted to log time trends. These data on thermal energy use are as follows (in millions of giga-calories):

	Industry	Household & Municipal	Losses	Total
1960	465	459	NA	NA
1965	731	674	8	1413
1970	1069	826	15	1910
1975	1419	987	20	2426

The measure of total industrial output used was constructed by weighting branch gross value of output measures (translated from the GNP values used in the model to GSP values used in Soviet sources by means of linking equations) by 1970 thermal power use estimates given

in Pavlenko and Nekrasov (1972, p.71). In this source, the following figures (first column) on thermal power use (in thousands of giga-calories per million rubles of output) are given. These were used to calculate ratios of boiler heat use per ruble of capital stock (second column):

Ferrous metals	3.0	5.2
Non-ferrous metals	3.0	NA
Chemicals	7.3	8.8
Petroleum products & coal	7.2	6.3
Machine building	2.4	4.9
Construction materials	6.9	8.2
Woodworking and paper	4.4	8.2
Food products	1.6	8.1
Soft goods	0.8	5.5

(When the ratios in the first column were applied to 1970 estimated gross output by branch, the total calculated boiler heat use was 1040 million giga-calories, which corresponds rather well with the figure of 1069 reported above.)

Considerably less information is available on furnace heat. Beschinskii and Kogan (1976, Appendix 4, p. 415) report a figure of 1815 million giga-calories of heat produced in 1971. In Nekrasov & Pervukhin (1977, Table 8-4, p. 161) the shares of total "boiler-furnace fuel" used in basic processing of ferrous metals and production of construction materials in 1970 are given as 13.9 and 2.9 per cent respectively. (Since the category of total boiler use is given separately we assume that this refers only to furnace use in these branches.) Using Campbell's figure of 315.2 million tons SFE of electric power plant fuel use in 1970, and the 37.9% share of total use given in the above source, we calculate total use of these fuels at 832

MTSFE, and use in ferrous metals and construction materials as 116 and 24 million tons SFE. Taking the conversion factor used in Beschinskii and Kogan (0.143 MTSFE per million giga-calories) and furnace heat to capital stock ratios of 37.8 and 12.1 giga-calories per thousand rubles, these estimates would give 809 and 169 million giga-calories of heat use. Although this accounts for only sixty per cent of total furnace heat use, no other information on branch use could be located. It is possible that some of the additional use is found within the fuel sectors themselves--in the production of coke and oil products--and some for the processing of non-ferrous metals. However, in order to generate estimates of furnace use we will simply use a weighted index of output in the former two sectors, and inflate it to the total value. (We have had to make the probably unrealistic assumption that the relationship enforced in 1970 remains constant over time.)

(E.23) TPRIND Boiler Heat Use Weighted Measure of Industrial Output

$$TPRIND = (-28.186 + 0.656\ (0.5\ (XOFM + XONF)))\ 3.0$$
$$+ (-4.168 + 0.1436\ XOCP + (-2.76 + 0.1568\ XOPP))\ 7.2$$
$$+ (0.663 + 0.8379\ XOMB)\ 2.4$$
$$+ (-2.3257 + 0.2421\ XOCH)\ 7.3$$
$$+ (-15.067 + 0.3158\ XOFP + (-2.562 + 0.0545\ XOPA)\ 4.4$$
$$+ (-2.334 + 0.1881\ XOCM)\ 6.9$$
$$+ (-77.142 + 1.4232\ XOSG)\ 0.8$$
$$+ (-78.522 + 1.6965\ XOPF)\ 1.6$$

(E.24) UTPRIND Industrial Use of Boiler Heat

$$\frac{UTPRIND}{TPRIND} = 1.892 - 0.285\ QLT50$$

(Fitted to data for 1960, 1965, 1970, 1975)

(E.25) UTPHHM Urban Household and Municipal Use of Boiler Heat

$$\frac{UTPHHM}{NPOPU} = -1.3289 + 2.3756\ QLT50$$

(Fitted to data for 1960, 1965, 1970, 1975.)

(E.26) UTPLOSS Transmission Losses of Thermal Power

$$\frac{UTPLOSS}{UTPTOT} = -0.0092 + 0.0054\ QLT50$$

(Fitted to data for 1965, 1970, 1975.)

(E.27) UTPTOT Total Thermal Energy Use

$$UTPTOT = UTPIND + UTPHHM + UTPLOSS + UTPF$$

where $UTPF = 1815 \left(\frac{0.82\ XOFM + 0.18\ XOCM}{104.33} \right)$

(104.33 is the value (0.82 XOFM + 0.18 XOCM) takes in 1971)

6. Thermal Energy Production

The two primary sources of low- and medium-temperature thermal energy are from co-generation with electrical power in the TETs and industrial and municipal boilers. There is also some secondary heat recovery which should also be included as a source. From Nekrasov & Pervukhin (1977, pp. 63-84) the following estimates were made for boiler heat output (in millions of giga-calories):

	Boilers	TETs	Secondary Recovery	Total
1960	NA	290.0	146.5	NA
1965	757.6	465.0	190.4	1413
1970	989.1	699.0	221.9	1910
1975	1235.0	918.0	273.0	2426

In the model production of thermal power in the TETs is calculated as a function of their generating capacity, and secondary recovery is an exogenous variable. Output of boilers is then determinded as a residual supply.

(E.28) XTPTETS Thermal Energy Output of TETs

XTPTETS = 25.24 + 14.96 KELTETS

(Fitted to data for 1960, 1965, 1970, 1975.)

7. Fuel Requirements for Thermal Energy Production

Since fuel requirements for the TETs are already included in the electric power equations, it is necessary only to calculate the needs for boilers and furnaces. Here the estimates of Campbell (1978) are used, and the same correction for use of coal as made in equation (E.15) above is introduced.

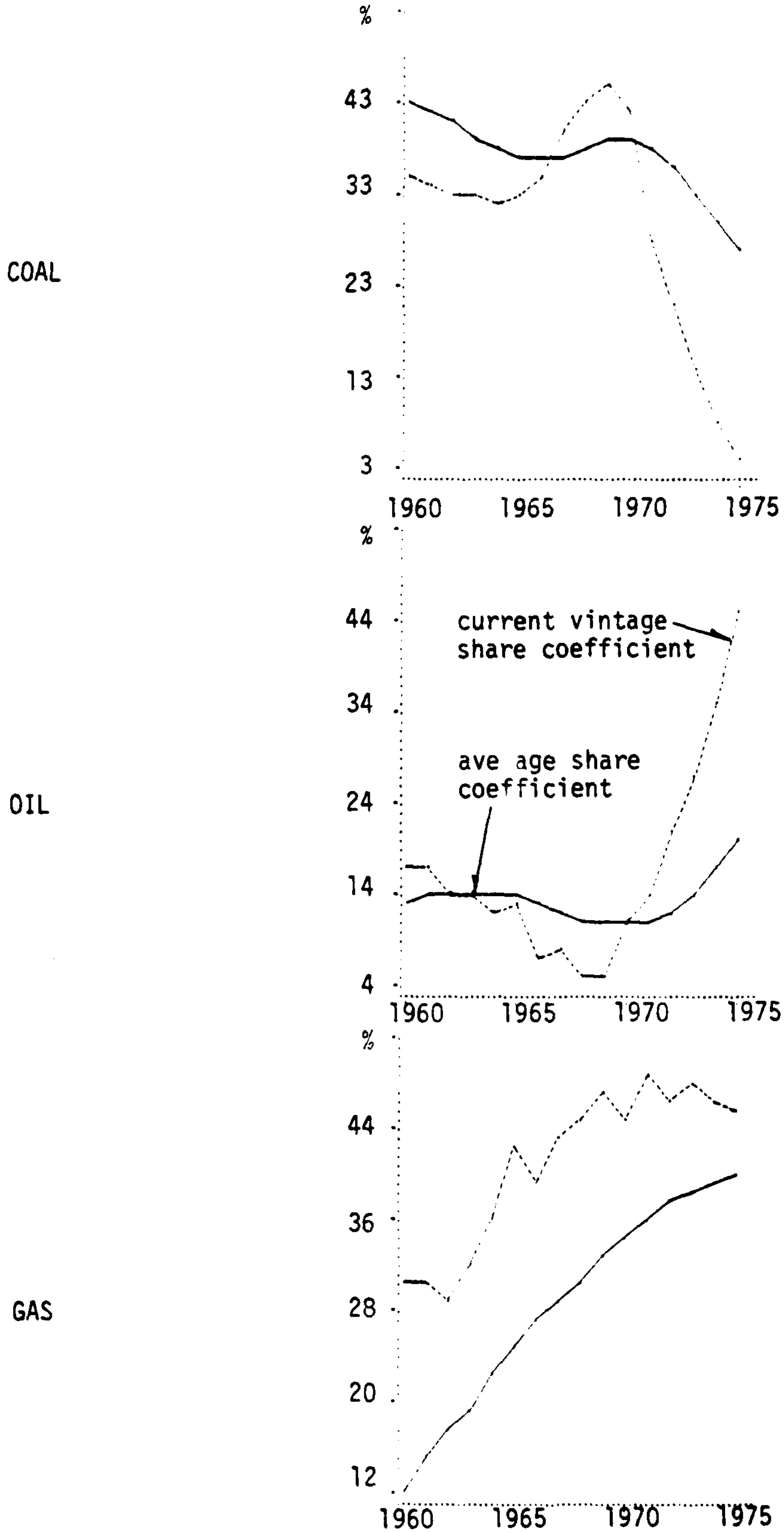
Fuel mix equations for boiler and furnace use are specified in the same manner as for electric power plants. The measures of capital stock by branch of industry are weighted by the thermal energy intensity of the branch's output (obtained using the (data presented in section 5), and a depreciation rate of 0.05 is used.

One problem with the procedure used here should be noted. Since Campbell in his accounting system nets out fuel use within the coal, oil, and gas industries, the same should be done here with the measure of thermal power use. Unfortunately, the information necessary to do this does not seem to be available. Thus both the denominator of equation (E.28) and the value of DKTP are not what we would have desired. (The energy sectors have not been included in the industrial capital stock index so that in the model they would not have any influence on the value of UFBF. But, nevertheless, there is a distortion in the weights used to construct the index.)

Plots of historic average and marginal fuel mix coefficients for boiler and furnace use, obtained in a manner similar to those of Figure 2, are presented in Figure 3.

Figure 3

FUEL MIX IN BOILERS & FURNACES



(E.29) UFBF Total Fuel Requirements of Boilers & Furnaces

$$\frac{\text{UFBF} - 0.15\ \text{UCOBF}}{\text{UTPTOT} - \text{XTPTETS} - \text{XTPSEC9}} = 0.376 - 0.0006\ \text{QT50}$$

(Fitted to data for 1965, 1970, 1975.)

(E.30) DKTP Thermal Energy Use Weighted Measure of Industrial Capital Stock

$$\begin{aligned} \text{DKTP} = 0.52\ [\ (\ &5.2\ \text{KIFM} + 4.9\ \text{KIMB} + 8.8\ \text{KICH} + 8.2\ \text{KIFP} \\ &+ 8.2\ \text{KICM} + 5.5\ \text{KISG} + 8.1\ \text{KIPF}\ )\ /\ 867.41\ ] \\ + 0.48\ [\ (\ &37.8\ \text{KIFM} + 12.1\ \text{KICM}\ )\ /\ 977.11\ ] \end{aligned}$$

(where 0.52 and 0.48 are the shares of boiler and furnace heat, and 867.41 and 977.11 are the 1970 values of the numerator expressions.)

(E.31) UCOBF, UPPBF UGABF Coal, Oil & Gas Use in Boilers and Furnaces

$$\frac{\text{U\&BF}}{\text{UFBF}} = \text{CM\&T9}\ \left(\frac{\text{DKTP} - 0.95\ \text{DKTP}_{-1}}{\text{DKTP}}\right)$$

$$+ \left(\frac{\text{U\&BF}_{-1}}{\text{UFBF}_{-1}}\right)\ 0.95\ \left(\frac{\text{DKTP}_{-1}}{\text{DKTP}}\right)$$

for & = CO, PP, GA

8. Non-Fuel Uses

The primary non-fuel uses of hydrocarbons are for coke required in the metallurgy industry, and oil and gas feedstocks in the chemical industry. Using data derived from Campbell (1978), these non-fuel uses were related to output measures of the corresponding sectors. The breakdown of total petrochemical feedstocks into its gas, light and heavy petroleum components is determined exogenously, with the enogenous aggregate value to be used as a control total.

(E.32) UCOKE Domestic Use of Coke

$$\frac{UCOKE}{XOFM} = 1.75 - 0.352 \quad QLT50$$

(Fitted to data for 1960, 1965, 1970, 1975.)

(E.33) UFSK Petrochemical Feedstocks

$$UFSK = -105.55 + 33.35 \ln(XOCH)$$

(Fitted to data for 1960, 1965, 1970, 1975.)

9. Domestic Use Aggegates

Various aggregations are performed on the fuel use components specified above for purposes of display and for use in balance equations. Since all the measures of fuel use considered above are calculated in terms of SFE units, and in most most cases, on the basis of data for actual use--that is, excluding losses and internal consumption--it is necessary to convert these values into their respective gross, natural unit values (million metric tons for oil and coal and billion of cubic meters for gas). Identities for this are included here.

(E.34) <u>UCO Coal Use</u>

UCO = UCOXELTP + UCOBF + UCOMF + UCOKE

(E.35) <u>UHPP Heavy Petroleum Product Use</u>

UHPP = UPPXELTP + UPPBF + UHPPMF9 + UHPPFSK9

(E.36) <u>ULPP Light Petroleum Product Use</u>

ULPP = ULPPMF + ULPPFSK9

(E.37) <u>UGA Gas Use</u>

UGA = UGAXELTP + UGABF + UGAFSK9

(E.38) <u>UFDIRECT Non-Fuel Uses</u>

UFDIRECT = UCOKE + UFSK

(E.39) <u>UFMF Motor-Fuel Use</u>

UFMF = UCOMF + UHPPMF9 + ULPPMF

(E.40) <u>UF Total Fuel Use (excluding losses and internal use)</u>

UF = UFXELTP + UFDIRECT + UFBF + UFMF

(E.41) <u>UCONT Coal Use (in natural units and including losses and internal use)</u>

UCONT = 1.4 (UCOXELTP + UCOBF + UCOMF)

+ (1.25 + 1.2 + 1.04) (UCOKE)

+ 0.12 XTCOP

where
1.4 is coal conversion factor for million ton/MTSFE
1.25 is adjustment factor for use of coke to produce byproducts
1.2 is adjustment factor for losses and internal use of coke
1.04 is coke conversion factor for million ton/MTSFE
0.12 is adjustment factor for losses and internal use of coal

(E.42) UPPNT Petroleum Product Use (in natural units including losses and internal uses)

$$UPPNT = 0.71\ (ULPP + UHPP) + 0.109\ XTOIP$$

where

0.71 is petroleum product conversion factor for million ton/MTSFE

0.109 is adjustment factor for losses and internal use

(E.43) UGANT Gas Use (in natural units and including losses and internal uses)

$$UGANT = 0.818\ UGA + 0.094\ \frac{XTGAN9}{1000}$$

where

0.818 is gas conversion factor for billion cubic meters/MTSFE

0.094 is adjustment factor for loses and internal use.

(E.44) UFT Total Fuel Use (in MTSFE and including losses and internal uses)

$$UFT = 0.6993\ UCONT + 1.43\ UPPNT + 1.195\ UGANT$$

V. Integration of the Energy and Fuel Component into SOVMOD

In order to integrate the new energy and fuel components into SOVMOD, it was necessary to change and supplement the factor input, production, and trade equations relating to the energy and fuel sectors. In certain cases, particularly for the oil and gas sector, the design of these relationships was changed so as to provide a more useful structure for scenario analysis.

1. Factor Allocation and Production Equations

The structure of relationships among variables depicting factor allocation and production for the oil and gas sectors is depicted in Figure 4. As can be seen, the controlling exogenous variables are annual meters drilled for exploratory wells and development wells, and annual length of gas pipeline constructed.

Both forms of drilling serve to determine investment costs in the petroleum products (combined oil and gas) sector. Drilling costs account for approximately 60% of all investment in the oil and gas industry, and it is likely that other investment--for oil and gas transport, storage and refining--is paced by the rate of drilling. Thus, this linking of drilling to total investment, although crude, is likely to provide a stable basis for projections. Based on data provided in Campbell (1976) the assumption was made that exploratory

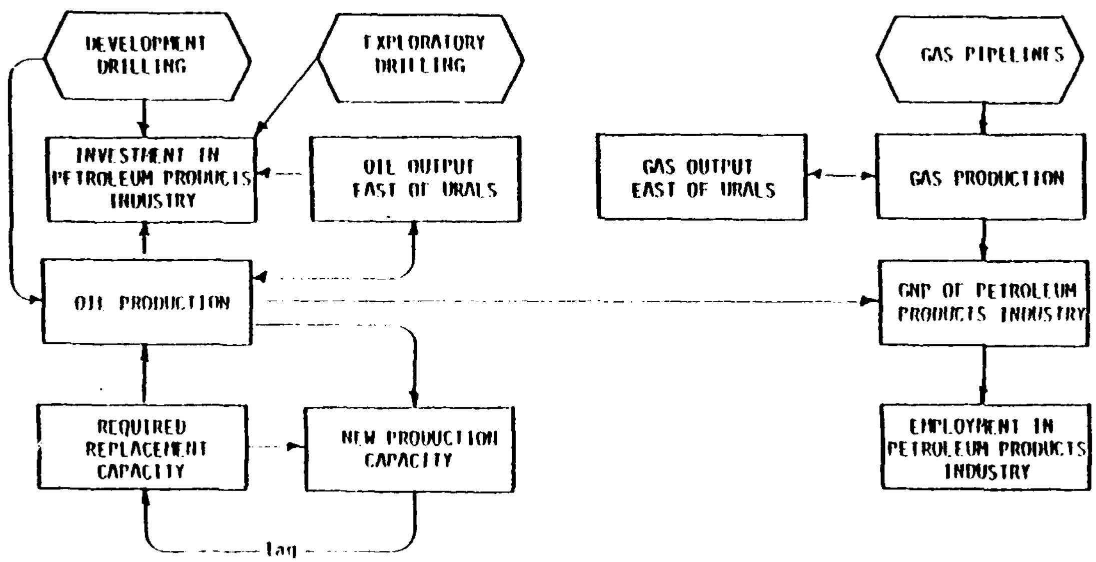


Figure 4

RELATIONSHIP OF THE OIL AND GAS PRODUCTION VARIABLES

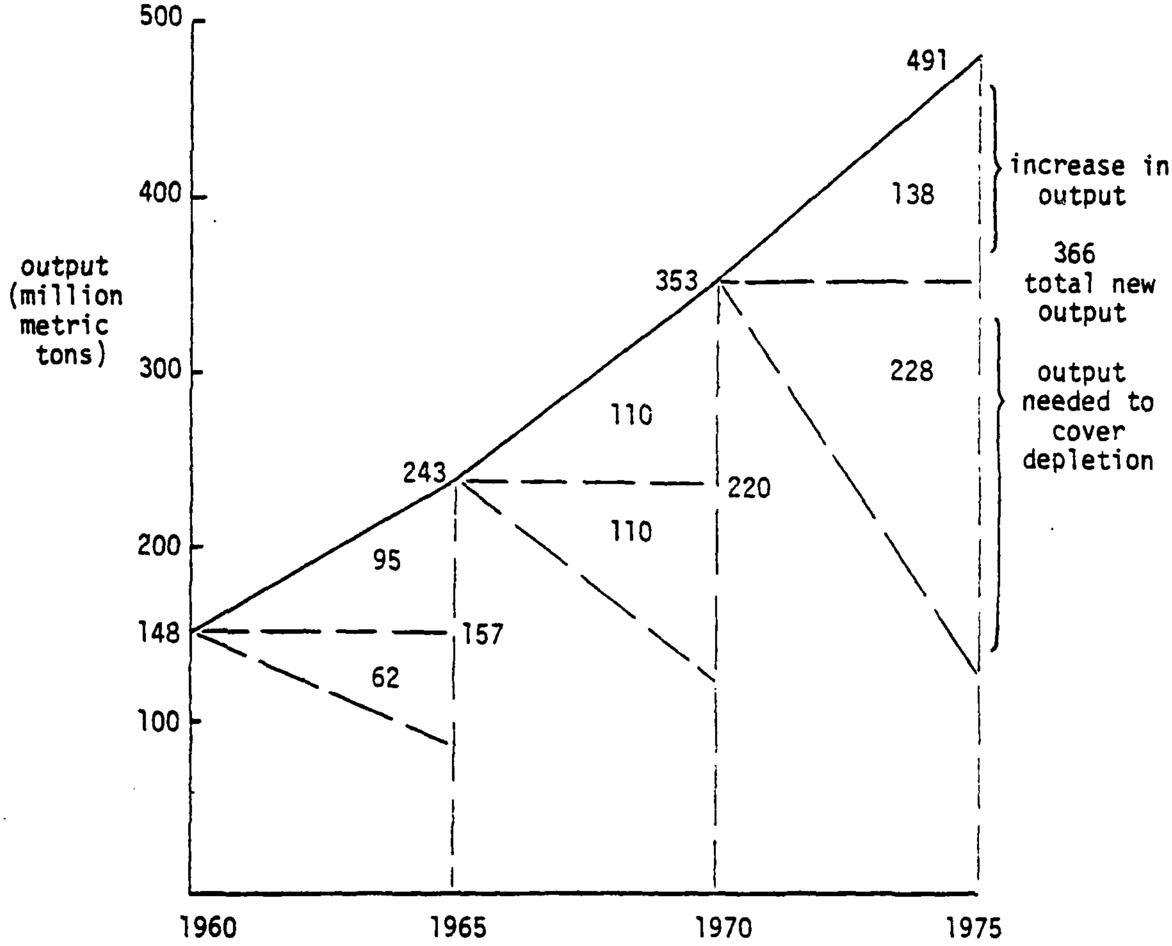
drilling was approximately two and a half times more costly than development drilling on a per meter basis.

Since there is a major shift underway in the location of new coal, oil and gas fields, it was felt that this should be reflected in the model. For example, as more wells have to be drilled in regions east of the Urals, we would expect to see an increase in investment cost per meter. (The data on cost of both types of drilling in various regions of the country as given in Sapozhinikov and Sokolov (1976, Table 23, p. 126) indicate just this.) Using historic data on total production and production east of the Urals (which includes Kazahkstan and Central Asia as well as the Siberian and Far East regions) we have fitted fuel output in the relatively well-developed western regions to time trends.

In determining oil output, we have used the following system. First, it is necessary to identify levels of new capacity production, for it is this measure of output which we will associate with the results of development drilling. New capacity is defined as the sum of two components. First, there is the increase in total output which can be easily calculated from the annual production figures provided in the Narkhoz. Second, and more difficult to find data for, is the amount of new capacity which is required to replace output from depleted wells. Figure 5, reproduced from Sapozhinikoz and Sokolov (1976, Figure 2, p. 7), indicates the magnitude and nature of these measures.

Figure 5

SOVIET NEW AND REPLACEMENT
OIL PRODUCTION CAPACITY



The rate of depletion of fields varies, depending on the natural characteristics of the deposit, and methods and rates of extraction. In general, however, it has been found that an assumption of an exponential rate of decline usually provides a simple, but good, description of the process.[14] Using the data on five year replacement totals given in Figure 5, we estimated an approximate time series of annual values for replacement by graphical interpolation. This series was then fitted to an exponential decline function in the following manner:

$$KREPOI_t = (a + b \ln(t)) \sum_{d=0}^{9} (e^{-0.2d} - e^{-0.2(d+1)}) \, KNEWOI_{t-d-1}$$

where $KREPOI_t$ is replacement output in year t, and $KNEWOI_t$ is total new capacity output in year t (which is equal to the increase in total output of that year--XTOIP - $XTOIP_{-1}$--plus replacement output --$KREPOI_t$). The estimated positive coefficient on the log time trend indicates that there has been a shift over the historic period toward more rapid depletion of fields.

New oil production (replacement plus increase) is specified as a function of the amount of development drilling carried out in the current and previous two years. This ratio of output to drilling over the period 1961-75, when regressed on time trend and regional output variables, showed a significant negative relationship with the former, and a positive relationship with the latter.

In the gas production equation, we have assumed that output is constrained by the availability of transport. Thus, total length of gas pipeline, an exogenous variable, sets the pace of output. As gas production has shifted to eastern fields, this has resulted in greater distances to be spanned by the pipelines. Thus, the regional location variable for gas is also included in the equation.

Gas and oil output are combined using 1970 price weights into a measure of total value of petroleum products production. This is, in turn, used to estimate a labor requirement equation for these sectors.

As explained previously, output of electrical power is determined by demand constrained by a output-to-capacity relationship. To tie this into the macro-model we have simply related value of output to the physical output level, generating capacity to value of capital stock, and employment to capacity.

For coal production, the existing factor allocation and production functions were retained. Physical output is then linked to the value of output obtained from the production function for the coal industry.

(E.45) XCOEU Output of Coal East of the Urals

$$\underset{(353.7)}{XTCOP - XCOEU} = \underset{(77.7)}{328.457} + \underset{(6.04)}{1.20262}\ QT50$$

$\bar{R}^2 = 0.781$ S.E. = 2.09 D.W. = 1.395

Sample Period 1965 - 1975

(E.46) XOIEU Output of Oil East of the Urals

$$\underset{(278.4)}{XTOIP - XOIEU} = \underset{(18.4)}{-3626.5} + \underset{(18.6)}{2440.4}\ QLT50 - \underset{(17.5)}{379.2}\ QLT50^2$$

$\bar{R}^2 = 0.997$ S.E. = 1.50 D.W. = 1.574

Sample Period 1965 - 1975

(E.47) XGAEU Output of Gas East of the Urals

$$\underset{(136623.)}{XTGAN - XGAEU} = \underset{(5.99)}{44334.} + \underset{(12.63)}{4292.5}\ QT50$$

$\bar{R}^2 = 0.935$ S.E. = 4063. D.W. = 1.269

Sample Period 1965 - 1975

(E.48) IIPP Investment in Petroleum Products Industry

$$\underset{(0.152)}{\frac{IIPP \times 1000.}{(IPPDRLD9 + 2.5\ IPPDRLX9)}} = \underset{(11.04)}{0.0419} + \underset{(9.13)}{0.1804}\ \frac{XOIEU}{XTOIP}$$

$$+ \underset{(14.74)}{0.0051}\ QT50$$

$\bar{R}^2 = 0.990$ S.E. = 0.0048 D.W. = 1.904

Sample Period 1956 - 1975

(E.49) KREPOI Oil Production Replacement Output

$$\frac{KREPOI}{\sum_{d=0}^{9} (e^{-0.2d} - e^{-0.2(d+1)}) \; KNEWOI_{t=-d-1}} = \underset{(9.34)}{-2.8} + \underset{(12.3)}{1.2} \; QLT50$$

(0.884)

$\bar{R}^2$ = 0.943 S.E. = 0.042 D.W. = 0.917

Sample Period 1966 -1975 (interpolated data)

(E.50) KNEWOI New Oil Production Capacity Output

$$KNEWOI = KREPOI + (XTOIP - XTOIP_{-1})$$

(E.51) XTOIP Oil Output

$$\frac{1000.\,(XTOIP - XTOIP_{-1}) + KREPOI}{(IPPDRLD9 + IPPDRLD9_{-1} + IPDRLD9_{-2})} = \underset{(10.6)}{3.10} - \underset{(2.80)}{0.0627} \; QT50$$

(2.75)

$$+ \underset{(5.60)}{5.016} \; \frac{XOIPEU}{XTOIP}$$

$\bar{R}^2$ = 0.848 S.E. = 0.13 D.W. = 1.492

Sample period 1961 - 1975

(E.52) XTGAN Gas Output

$$\frac{XTGAN}{HPTGA9} = \underset{(65.1)}{3135.4} - \underset{(4.45)}{673.78} \; \frac{XGAEU}{XTGAN}$$

2930.8)

$\bar{R}^2$ = 0.654 S.E. = 48.46 D.W. = 2.109

Sample Period 1965 - 1975

(E.53) XOPP Output of Petroleum Products Industry

$$XOPP = (0.6093 \frac{XTOIP}{353.039} + 0.3907 \frac{XTGAN}{197.945})\ 100.$$

(E.54) NMIPP Employment in Petroleum Products Industry

$$\underset{(3.09)}{\frac{NMIPP}{XOPP}} = \underset{(35.77)}{12.255} - \underset{(26.86)}{3.18}\ QLT50$$

$\bar{R}^2 = 0.980$ S.E. = 0.123 D.W. = 0.979

Sample Period 1960 - 1975

(E.55) XTCOP Coal Production

$$\underset{(564.3)}{XTCOP} = \underset{(4.76)}{39.42} + \underset{(11.63)}{7.16}\ XOCP - \underset{(2.13)}{42.73}\ QLT50$$

$\bar{R}^2 = 0.995$ S.E. = 5.803 D.W.= 1.977

Sample Period 1955 - 1975

(E.56) KELPC Electrical Power Generating Capacity

$$\underset{(5.40)}{\frac{KELPC}{KIEP}} = \underset{(36.3)}{13.878} - \underset{(22.2)}{2.918}\ QLT50$$

$\bar{R}^2 = 0.969$ S.E. = 0.146 D.W. = 1.457

Sample Period = 1960 - 1976

(E.57) XOEP Output of Electric Power Industry

$$\underset{(85.73)}{XOEP} = \underset{(4.54)}{4.949} + \underset{(242.7)}{0.1373}\ XELP - \underset{(4.43)}{2.215}\ QLT50$$

$\bar{R}^2 = 1.000$ S.E. = 0.10 D.W. = 1.566

Sample Period 1960 - 1975

(E.58) NMIEP Employment in Electric Power Industry

$$\frac{NMIEP}{KELPC} = \underset{(13.7)}{16.07} - \underset{(18.5)}{3.61}\, QLT50 - \underset{(1.95)}{6.36} \frac{KELHPC9}{KELPC}$$

(4.40)

$\bar{R}^2 = 0.989$ S.E. $= 0.091$ D.W. 1.063

Sample Period 1960 - 1975

2. Fuel Trade Equations

The fuel trade equations have been designed to fulfill three functions:

(1) to separately identify trade flows by each major type--oil, gas, coal--so as to allow separate treatment of each in scenario analysis with the model;

(2) to link the various trade variables already in the previous model to the more detailed fuel trade categories now introduced; and,

(3) to provide net fuel export values for the fuel balance equations.

For explanatory variables, we have used various measures of economic activity in the foreign trade regions, and the hard currency debt position (represented by the difference between outstanding debt, FDEBT, and hard currency holdings, FSTK). Since there may be diversion of trade from the East European countries to hard currency trade when debt is high, this latter variable is found in the coal and oil equations for trade with both East Europe and the rest of the world. In the former equations the sign is negative; in the latter popsitive.

It was also found that the price of oil had a significant impact in explaining oil exports to the rest of the world. This variable has a negative sign, which indicates that the Soviet planners may set their annual targets for oil exports in terms of a certain amount of hard currency earnings, so that if prices rise less oil is exported.

Since gas transport is largely by pipeline, and the pipelines extend primarily from the U.S.S.R. across East Europe to West Europe, there is evident some complimentarity in exports to both regions. This was expressed in the model by having gas exports to East Europe be a function of both GNP in that region and the level of gas exports to West Europe. The price of gas was found to have a positive impact on trade with Western Europe and so was included, along with rest-of-world economic output levels, in that equation.

In order to make compatible the above flows, which are in physical units, to existing trade variables which are in current dollar values, it is necessary to introduce price variables for each fuel and region. The prices of fuels in trade with the East European countries are determined endogenously as a function of rest of the world prices given exogenously. We specify the relationship between these two sets of values in the following manner. We assume that there is a permanent structural difference between the two due to transport cost differences and the fact that the Soviet Union and East European countries are joined in a type of customs union.[15] This may be represented as follows:

$$p^{ee} = (1 + a)\, p^{rw}$$

where p^{ee} and p^{rw} are the two regional prices. But with the new agreement within the CMEA to slowly reduce the differences between world and internal prices, we may observe the gap between the two prices being reduced, say in the following manner,

$$p^{ee} - p^{ee}_{t-i} = b(p^{rw} - p^{ee}_{t-1})$$

Both relationship can be combined, as in the following specification:

$$p^{ee} = (1 - b)\ p^{ee}_{t-1} + (a + b)\ p^{rw}$$

which is the form used in the model.

We have not explicitly included fuel imports in the model. (They can be seen to be the residuals in the balance equations.)

(E.59) <u>EFEECO Export of Coal and Coke to East Europe</u>

$$EFEECO = 100.246\ YCMEA9 - 0.478\ (FDEBT - FSTK)$$
(14659.6) (32.11) (3.24)

$\bar{R}^2 = 0.797$ S.E. = 1055 D.W. = 2.199

Sample Period 1965 - 1975

(E.60) <u>EFEEOI Export of Oil to East Europe</u>

$$EFEEOI = -38674.6 + 525.25\ YCMEA - 1.31\ (FDEBT - FSTK)$$
(40685.) (11.76) (21.41) (4.39)

$\bar{R}^2 = 0.993$ S.E. = 1156. D.W.= 2.152

Sample Period 1965 - 1975

E.61) <u>EFEEGA Export of Gas to East Europe</u>

$$EFEEGA = -4599.1 + 45.35\ YCMEA + 0.1012\ EFRWGA$$
(2774.) (19.8) (27.5) (8.00)

$\bar{R}^2 = 0.997$ S.E. = 94.5 D.W.= 2.256

Sample Period 1965 - 1975

(E.62) <u>EFRWCO Export of Coal and Coke to Rest of the World</u>

$$EFRWCO = 18324.9 - 0.380\ EFEECO + 0.192\ (FDEBT - FSTK)$$
(13174.) (9.12) (2.55) (1.48)

$\bar{R}^2 = 0.319$ S.E. = 792.1 D.W. = 2.041

Sample period 1965 - 1975

(E.63) EFRWOI Export of Oil to Rest of the World

$$\underset{(56300.)}{EFRWOI} = \underset{(6.31)}{38272.7} + \underset{(2.42)}{191.06}\ ZWAIP7/9 + \underset{(3.94)}{2.309}\ (FDEBT - FSTK) - \underset{(2.20)}{173.2}\ EPRWOI$$

$\bar{R}^2 = 0.880$ S.E. = 2367. D.W. = 2.513

Sample Period 1960 - 1975

(E.64) EFRWGA Export of Gas to Rest of World

$$\underset{(3700.)}{EFRWGA} = \underset{(10.28)}{-23072.4} - \underset{(4.85)}{131.985}\ ZWAIP7/9 + \underset{(9.81)}{1001.98}\ EPRWGA$$

$\bar{R}^2 = 0.972$ S.E. = 781.69 D.W. = 3.183

Sample Period 1968 - 1975

(E.65) EFTEP Total Exports of Electricity

$$\underset{(5.73)}{EFTEP} = \underset{(11.79)}{-12.16} + \underset{(17.69)}{0.1143}\ YCMEA9$$

$\bar{R}^2 = 0.969$ S.E. = 0.669 D.W. 1.316

Sample Period 1965 - 1975

(E.66) EPEECO Export Price of Coal to East Europe

$$\underset{(16.25)}{EPEECO} = \underset{(10.31)}{0.6797}\ EPEECO_{-1} + \underset{(6.72)}{0.3867}\ EPRWCO9$$

$\bar{R}^2 = 0.815$ S.E. = 1.72

Sample Period 1965 - 1975

(E.67) EPEEOI Export Price of Oil to East Europe

$$EPEEOI = 0.7960\ EPEEOI_{-1} + 0.1589\ EPRWOI9$$

(14.35) (6.68) (3.02)

$\bar{R}^2 = 0.501$ S.E. = 3.15

Sample Period 1965 - 1975

(E.68) EPEEGA Export Price of Gas to East Europe

$$EPEEPGA = -0.0540\ EPEEGA_{-1} + 1.1967\ EPRWGA9$$

(15.81) (0.31) (6.9)

$\bar{R}^2 = 0.882$ S.E. = 1.49

Sample Period 1968 - 1975

(E.69) EFUELEE Export of Fuels to East Europe

EFUELEE = (EFEECO x EPEECO +

EFEEOI x EPEEOI +

EFEEGA x EPEEGA) PREX9/1000

(E.70) EFUELRW Export of Fuels to the Rest of the World

EFUELRW = (EFRWCO x EPRWCO9 +

EFRWOI x EPRWOI9 +

EFRWGA x EPRWGA9) PREX9/1000

(E.71) EFUELDW Export of Fuels to the Developed West

$$\frac{EFUELDW}{EFUELRW} = -0.2442 + 0.2807\ QLT50$$

(0.566) (1.90) (6.33)

$\bar{R}^2 = 0.722$ S.E. = 0.046 D.W. = 1.759

Sample Period 1960 - 1975

(E.72) ENFRMCM Export of Raw Materials and Semifabricants to CMEA Minus Fuel Exports to East Europe

$$\frac{ENFRMCM}{PM2HUS} = -12.472 + 0.228\ YCMEA9 + 6.834\ PFUHUS9$$

(25.92) (3.76) (24.0) (1.93)

R^2 = 0.980 S.E. = 1.32 D.W. = 2.125

Sample Period 1960 - 1975

(E.73) ERMCM Export of Raw Materials and Semifabricates to CMEA Countries

ERMCM = EFUELEE + ENFRMCM

3. Balance Equations

A set of identities for examining the balance between supply and use for coal, oil, and gas are included in the model. Since we have not explicitly identified fuel imports or changes in inventories and reserves elsewhere in the model, any residual value in the balances could be identified with these categories.

At the present time, it is intended that these balance equations be used by the analyst as a guide in making adjustments to the model solution when in the process of scenario analysis or forecasting. We plan eventually to incorporate into SOVMOD an endogenous adjustment mechanism for maintaining consistency between supply and demand for output of all sectors, and at that time, these balance equations will be incorporated into that system.[15]

(E.74) GCO Coal Balance

GCO = XTCOP - UCONT - EFEECO - EFRWCO

(E.75) GOI Oil Balance

GOI = XTOIP - UPPNT - EFEEOI - EFRWOI

(E.76) GGA Gas Balance

GGA = XTGAN/1000 - UGANT - EFEEGA - EFRWGA

FOOTNOTES

[1]CIA (1975, 1977b, 1977c, 1977d).

[2]CIA (1977a).

[3]Dienes (1977), Doboze (1978), Hardt, et al. (1977).

[4]A full description of the origins and early results of the project is provided in Green and Higgins (1977). Each phase of the model's development has been documented in annual project reports. The latest of these is Green, et al. (1976). A complete list of the project's publications and working papers will be made available upon request to the Strategic Studies Center, SRI International, Washington, D.C..

[5]See CIA (1975) and Kazmer (1976).

[6]The general approach used here--of first determining energy requirements of users and then estimating supply of particular fuels that can satisfy these energy requirements--is similar to that proposed by Frisch (1965), pp. 231-249.

[7]See Johansen (1960).

[8]See Bond and Rutan (1978).

[9]Also, use of energy sector models such as the linear programming models of Tretyakova and Batalina (1963) or Dienes (1973) might be useful for this purpose.

[10]Campbell (1978). Another potential source of detailed information on energy and fuel flows in the Soviet economy are the input-output accounts that have been compiled periodically by the Soviets (1959, 1966, 1972, and 1977) and reconstructued by Western analysts. (See Treml, et al. (1972) and Treml, ed. (1977).) These would be of great value in studying demand by particular branches.of industry and sectors of the the economy. Two attributes of these accounts have led to our not using them at this time. First, the reported flows are for sector of supply (coal, coke, oil, gas, and electrical/thermal power) to sector of use. Thus it is not possible to distinguish type of fuel use (direct motor, electric power generation, boier and furnace use) as has been done in the present study. Secondly, the reported flows are in value terms only. Since the prices of particular types of fuel witin each sector (especially for petroleum products) varies greatly and the composition of these types going to each branch also varies, these

values flows do not correspond well to the underlying physical flows (The existence of some differential pricing also complicates the interpretation of the value figures.) It seems that the price and supply information necessary for converting these input-output value flows into physical flows are avilable in published Soviet sources. (This information is based on a conversation with Albina Tretyakova.) But this has not been done at the present time.

[11]The estimate of 20 miles per gallon for fuel efficiency was made using a auto fuel use equation estimated for the Wharton EFA, Inc., automobile model and data on Soviet passenger car specifications from Edwards (1973), Table 5, p. 299.

[12]The figure of 0.25 automobiles per capita is approximately that of Italy in 1972.

[13]The values of UFLPPNT were calculated by subtracting estimates of auto fuel use from estimates of total light petroleum product use outside the trasport sector.

[14]Bradley (1967), pp. 22-23 and Chapter 4, pp. 42-60.

[15]This representation of price relationships was prompted by the specifications used in Toda (1978).

[16]See Bond and Rutan (1978).

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APPENDIX: GLOSSARY OF VARIABLES

AVCP70
Value of agricultural current purchases
Billion 1970 rubles

CMCOE9
Vintage coefficients for coal in electric power plant fuel
Ratio

CMCOT9
Vintage coefficient for coal in boiler and furnace fuel
Ratio

CMGAE9
Vintage coefficient for gas in electrical power plant fuel
Ratio

CMGAT9
Vintage coefficient for gas in boiler and furnace fuel
Ratio

CMPPE9
Vintage coefficient for petroleum products in electrical power plant fuel
Ratio

CMPPT9
Vintage coefficient for petroleum products in boiler and furnace fuel
Ratio

DKTP
Thermal energy use weighted measure of industrial capital stock
Billion 1970 rubles

EAUTO
Exports of automobiles
Thousands

EAUTOD
Exports of automobiles in disassembled form
Thousands

EFEECO

Exports of coal to East Europe
Million Tons

EFEEGA

Exports of gas to East Europe
Billion Cubic M.

EFEEOI

Exports of oil to East Europe
Million Tons

EFRWCO

Export of coal to rest of the world
Million Tons

EFRWGA

Exports of gas to rest of the world
Billion Cubic

EFRWOI

Exports of oil to rest of the world
Million Tons

EFTEP

Total export of electricity
Billion KWH

EFUELDW

Exports of fuels to the developed West
Million Current Dollars

EFUELEE

Exports of fuels to East Europe
Million Current Dollars

EFUELRW

Exports of fuels to rest of the world
Million Current Dollars

ENFRMCM

Exports of raw materials & semi-fabricants to CMEA minus fuel exports to East Europe
Million Current Dollars

ENETCOW

Net exports of coal
Million Tons

ENETGAW

Net exports of gas
Billion Cubic Meters

ENETOIW
Net exports of crude oil and petroleum products
Million Tons

EPEECO
Export price of coal to East Europe
Foreign Trade Rubles Per Ton

EPEEGA
Export price of gas to East Europe
Foreign Trade Rubles Per Thousand Cubic Meters

EPEEOI
Export price of oil to East Europe
Foreign Trade Rubles Per Ton

EPRIND
Industry output index weighted by branch electric power requirements
Index

EPRWCO9
Export price of coal to rest of world
Foreign Trade Rubles Per Ton

EPRWGA9
Export price of gas to rest of world
Foreign Trade Rubles Per Thousand Cubic Meters

EPRWOI9
Export price of oil to rest of world
Foreign Trade Rubles Per Ton

ERMCM
Exports of raw materials and semi fabricants to CMEA
Million Current Dollars

FDEBT
Outstanding foreign debt at end of year
Million Current Dollars

FSTK
Accumulated hard currency holdings since 1959
Million Current Dollars

GCO
Coal balance
Million Tons

GOI
Oil balance
Million Tons

HFTOT
Total freight turnover
Billion Ton-Kilometers

HPTGA9
Total length of gas pipelines
Thousand Kilometers

IIPP
Capital investment, petroleum products industry
Billion 1970 rubles

IPPDRL
Total drilling for oil and gas
Thousand Meters

IPPDRLD9
Development drilling for oil and gas
Thousand Meters

IPPDRLX9
Exploratory drilling for oil and gas
Thousand Meters

KAIR
Agricultural fixed capital (mean year; 1955 prices)
Billion Rubles

KAUTO
Estimated stock of autos
Thousands

KCR
Basic funds, construction (January 1, 1955 prices)
Billion Rubles

KELAPC9
Nuclear electric power capacity
Million Kilowatts

KELHPC9
Hydro-electric power capacity
Million Kilowatts

KELPC
Total electrical energy production capacity
Million Kilowatts

KELTETS
Capacity of thermal-electric stations producing thermal power
Million Kilowatts

KELTPC9
Thermal electric power capacity
Million Kilowatts

KICH
Capital stock, chemicals and petrochemicals (January 1)
Billion 1955 Rubles

KICM
Capital stock, construction materials
Billion 1955 Rubles

KICP
Capital stock, coal products
Billion 1955 Rubles

KIEP
Capital stock, electric power
Billion 1955 Rubles

KIFM
Capital stock, ferrous metals
Billion 1955 Rubles

KIFP
Capital stock, forest products
Billion 1955 Rubles

KIMB
Capital stock, machine-buillding and metal-working
Billion 1955 Rubles

KIPF
Capital stock, processed foods
Billion 1955 Rubles

KIPP
Capital stock, petroleum products
Billion 1955 Rubles

KISG
Capital stock, soft goods
Billion 1955 Rubles

KITOT
Capital stock, total industry
Billion 1955 Rubles

KNEWOI
New oil production capacity output
Million Tons

KREPOI
Oil production replacement output
Million Tons

NMD9
Military manpower
Million Persons

NMIEP
Average annual employment, branchielectroenergy
Thousand persons

NMIPP
Average annual employment, branch: petroleum products
Thousand persons

NPOPU
Population urban (end year)
Millions

NPOP9
Total population
Millions

PFUHUS9
Price ratio for Hungarian imports from socialist nations: fuels/materials
1970=100

PM2HUS9
Hungarian import price, socialist, ctn 2: raw materials and fuels
1960=100

PREX9
Official exchange rate of ruble in dollars
Current U.S. Dollars Per Ruble

QLT50
Log time trend 1950=0
None

QT50
Time variable: 1950=1, 1973=24
None

RHRLE9
Ratio of electrified to total railway lines
Ratio

TPRIND
Thermal energy use weighted measure of industrial output
Index

UCO
Domestic coal use (excld. losses and internal use)
MTSFE

UCOBF
Coal use in boilers and furnaces
MTSFE

UCOKE
Domestic coke use (excld. losses and internal use)
MTSFE

UCOMF
Coal use as motor fuel
MTSFE

UCONT
Total domestic coal use (incld. losses and internal use)
Million Tons

UCOXELTP
Coal use in thermal-electric power generation
MTSFE

UELAG
Agricultural use of electricity
Billion KWH

UELCN
Estimated construction use of electricity
Billion KWH

UELHHM
Urban household and municipal use of electricity
Billion KWH

UELIN
Industrial use of electricity
Billion KWH

UELOSS
Transmission losses of electricity
Billion KWH

UELOT
Other uses of electricity (construction and HHM)
Billion KWH

UELTR
Transportation use of electricity
Billion KWH

UF
Domestic fuel use (excluding losses and internal use)
MTSFE

UFBF
Total fuel use in boilers and furnaces
MTSFE

UFDIRECT
Total direct use of fuels (coke and feedstocks)
MTSFE

UFLFFNT
Use of light petroleum products for fuel outside transport sector (excluding.auto)
MTSFE

UFLPPT
Use of light petroleum products in transport sector
MTSFE

UFMF
Total fuel use in motors
MTSFE

UFMOTORT
Use of coal and light petroleum products in transport sector
MTSFE

UFSK
Petrochemical feedstocks
MTSFE

UFT Total fuel use (including losses and internal use)
MTSFE

UFXELTP
Fuel use in thermo-electric power plants
MTSFE

UGA
Domestic gas use (excld. losses and internal use)
MTSFE

UGABF
Gas use in boilers and furnaces
MTSfe

UGAFSK9
Gas feedstocks
MTSFE

UGANT
Total domestic gas use (including losses and internal use)
Billion Cubic M.

UGAXELTF
Gas use in thermol-electric power generation
MTSFE

UHPP
Domestic heavy petroleum products use (excld. losses and internal use)
MTSFE

UHPPFS9
Heavy petroleum products feedstocks
MTSFE

UHPPMF9
Heavy petroleum products use as motor fuel (primarily naval)
MTSFE

ULPP
Domestic light petroleum products use (excld. losses and internal use)
MTSFE

ULPPFSK9
Light petroleum products feedstocks
MTSFE

ULPPMF
Light petroleum products use as motor fuel
MTSFE

UPPBF
Petroleum products use in boilers and furnaces
MTSFE

UPPNT
Total domestic petroleum products use (incld. losses and internal use)
Million Tons

UPPXELTP
Petroleum use in thermal-electric power generation
MTSFE

UTPHHM
Thermal power use in households and municipalities
Million Giga-Calories

UTPIND
Thermal power use in industry
Million Giga-Calories

UTPLOSS
Thermal power transmission losses
Million Giga-Calories

UTPTOT
Total thermal power use
Million Giga-Calories

XAGTN
Normal agricultural output
Billion 1970 rubles

XAGT70
Total net form output, 1970 prices
Billion 1970 rubles

XAUTO
Production of automobiles
Thousands

XCOEU
Coal production east of Urals
Million Tons

XELAP
Output of atomic power stations
Billion KWH

XELHP
Hydro-electric energy production
Billion KWH

XELP
Total electrical energy production
Billion KWH

XELPCTL9
Ratio of centralized to total electrical power output
Ratio

XELTP
Output of conventional thermal-electric power stations
Billion KWH

XGAEU
Natural gas production east of Urals
Million Cubic Meters

XOCH

Output: chemicals and petrochemicals
1970=100

XOCM

Output: construction materials
1970=100

XOCN

Output: construction
1970=100

XOCP

Output: coal products
1970=100

XOEP

Output: electric power
1970=100

XOFM

Output: ferrous metals
1970=100

XOFP

Output: forest products
1970=100

XOIEU

Oil production east of Urals
Million Tons

XOIN

Output: total industry
1970=100

XOMB

Output: machine-building and metal-working
1970=100

XONF

Output: non-ferrous metals
1970=100

XOPA

Output: paper and pulp
1976=100

XOPF

Output: procesed food
1970=100

XOPP

Output: petroleum products
1970=100

XOSG

Output: soft goods
1970=100

XTCOP

Total coal production
Million Tons

XTGAN

Total natural gas production
Million Cubic Meters

XTOIP

Total oil production including gas condensates
Million Tons

XTOIP9

Total oil production (including gas condensates)
Million Tons

XTPSEC9

Secondary recovery of thermal power
Million Giga-Calories

XTPTETS

Thermal power output of electric power stations
Million Giga-Calories

YCMEA9

Net material product in constant prices, CMEA
1963 = 100

ZWAIP7/9

Weighted average, industrial production index in 7 countries
1972 = 100

ZWUM

Real urban and military earnings
Billion 1970 rubles